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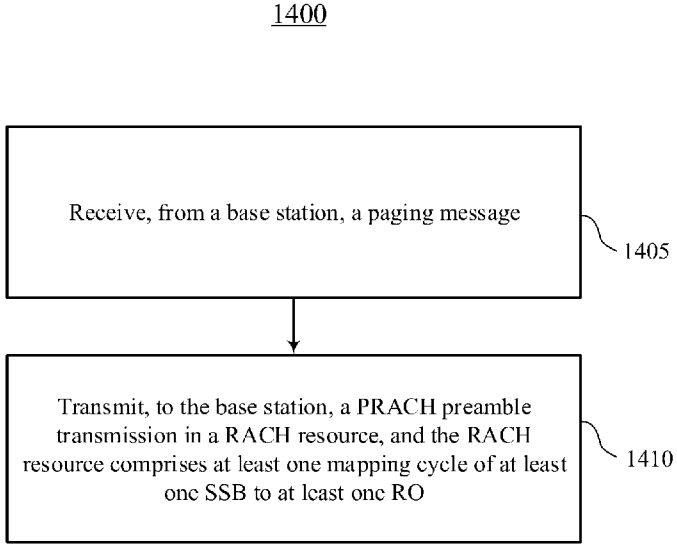

FIG. 14

(57) Abstract: Various aspects of the present disclosure relate to a physical random access channel (PRACH) preamble transmission. In an aspect, a user equipment receives a paging message from a base station. The user equipment transmits a PRACH preamble transmission in a RACH resource to the base station. The RACH resource comprises at least one mapping cycle of at least one SSB to at least one RO.

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PRACH PREAMBLE TRANSMISSION

[0001] The present disclosure relates to wireless communications, and more specifically to a physical random access channel (PRACH) preamble transmission, in particular, for network energy saving.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] In long-term evaluation (LTE) and new radio (NR), a UE in a radio resource control (RRC) IDLE state (or in an RRC INACTIVE state in NR) starts a random access (RA) procedure if the UE receives a paging message indicating downlink (DL) data arrival for the UE, or if uplink (UL) data arrives for the UE. For the RA procedure, there are still some issues to be addressed.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support a PRACH preamble transmission, especially, for network energy saving..

[0005] Some implementations of the method and apparatuses described herein include, receiving, from a base station, a paging message, and transmitting, to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

[0006] Some implementations of the method and apparatuses described herein may further include determining a RO among one or more ROs of a mapping cycle for PRACH preamble transmission based on an association between the at least one PO and the at least one mapping cycle.

[0007] Some implementations of the method and apparatuses described herein may further include determining a preamble of the PRACH preamble transmission based on a preamble start index and a paging record index.

[0008] Some implementations of the method and apparatuses described herein may further include receiving, from the base station, a random access response (RAR) for the PRACH preamble transmission after transmitting the preamble, and stopping a random access (RA) procedure.

[0009] In some implementations of the method and apparatuses described herein, the number of the at least one mapping cycle may be determined based on at least one of a number of supported paged UEs of the paging message in a paging occasion (PO), a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource.

[0010] In some implementations of the method and apparatuses described herein, the number of the at least one mapping cycle may be determined by in the case that one SSB is associated with one or more ROs, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, and a number of preambles of a RO, or in the case that multiple SSBs are associated with one RO, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, a number of preambles of a RO, and a number of the multiple SSBs.

[0011] In some implementations of the method and apparatuses described herein, the association between the at least one PO and the at least one mapping cycle may be based on indexed POs associated with a same PRACH resource and indexed mapping cycles of the PRACH resource.

[0012] In some implementations of the method and apparatuses described herein, in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle, a PO is associated with a RO with the same index, in the case that a first number of the at least one PO is equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs may be associated with a RO with the same index, and a number of POs in the set of POs is equal to the third number, or in the case that a second number of the at least one mapping cycle may be equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO may be associated with a RO with the same index, and a number of paging records in the set of paging records is equal to a number of paging records in a PO divided by the fourth number.

[0013] In some implementations of the method and apparatuses described herein, the preamble may be determined by in the case that one SSB is associated with one or more ROs, determining an index of the preamble based on the preamble start index, the paging record index, and a number of preambles of a RO; and in the case that multiple SSBs are associated with one RO, determining an index of the preamble based on the preamble start index, an index of a first preamble among a set of preambles associated with the multiple SSBs, the paging record index, and a number of preambles of an SSB in a RO.

[0014] In some implementations of the method and apparatuses described herein, the preamble start index may be configured via a radio resource control (RRC) message, the preamble start index may be configured via a medium access control (MAC) message, the preamble start index may be configured via a physical layer message, the preamble start index may be predefined.

[0015] In some implementations of the method and apparatuses described herein, the PRACH preamble transmission may be transmitted by transmitting the preamble on the determined RO to the base station.

[0016] In some implementations of the method and apparatuses described herein, the RAR may comprise a timing advance (TA) command and a cell radio network temporary

identifier (C-RNTI), or the RAR may comprise a TA command, a C-RNTI, and a downlink (DL) grant for scheduling a transmission of an RRC setup message or an RRC resume message.

[0017] In some implementations of the method and apparatuses described herein, the RACH resource may be configured by a paging downlink control information (DCI), the RACH resource may be configured by a paging record, the RACH resource may be configured by a paging message, the RACH resource may be configured by a paging early indication (PEI), the RACH resource may be triggered by a paging DCI, the RACH resource may be triggered by a paging record, the RACH resource may be triggered by a paging message, or the RACH resource may be triggered by a PEI.

[0018] Some implementations of the method and apparatuses described herein include, transmitting a paging message to a user equipment (UE), and receiving a physical random access channel (PRACH) preamble transmission from the UE in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

[0019] Some implementations of the method and apparatuses described herein may further include transmitting a random access response (RAR) to the UE for the PRACH preamble transmission after receiving the preamble.

[0020] In some implementations of the method and apparatuses described herein, the number of the at least one mapping cycle may be determined based on at least one of a number of supported paged UEs of the paging message in a paging occasion (PO), a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource.

[0021] In some implementations of the method and apparatuses described herein, in the case that one SSB may be associated with one or more ROs, the number of the at least one mapping cycle may be determined based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource and a number of preambles of a RO, or in the case that multiple SSBs are associated with one RO, the number of the at least one mapping cycle may be determined based on the number of supported paged UEs in the paging message, a number of the at least one PO

associated with the RACH resource, a number of preambles of a RO and a number of the multiple SSBs.

[0022] In some implementations of the method and apparatuses described herein, in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle, a PO may be associated with a RO with the same index, in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs may be associated with a RO with the same index, a number of POs in the set of POs is equal to the third number, or in the case that a second number of the at least one mapping cycle may be equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO is associated with a RO with the same index, wherein a number of paging records in the set of paging records is equal to a number of paging records in a PO divided by the fourth number.

[0023] In some implementations of the method and apparatuses described herein, the PRACH preamble transmission may be received by receiving a preamble of the PRACH preamble transmission from the UE.

[0024] In some implementations of the method and apparatuses described herein, the RAR may comprise a timing advance (TA) command and a cell radio network temporary identifier (C-RNTI), or the RAR may comprise a TA command, a C-RNTI, and a downlink (DL) grant for scheduling a transmission of an RRC setup message or an RRC resume message.

[0025] In some implementations of the method and apparatuses described herein, the RACH resource may be configured by a paging downlink control information (DCI), the RACH resource may be configured by a paging record, the RACH resource may be configured by a paging message, the RACH resource may be configured by a paging early indication (PEI), the RACH resource may be triggered by a paging DCI, the RACH resource may be triggered by a paging record, the RACH resource may be triggered by a paging message, or the RACH resource may be triggered by a PEI.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1A illustrates an example of a wireless communications system that supports a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0027] FIG. 1B illustrates an example of 4-step access procedure associated with aspects of the present disclosure.

[0028] FIG. 1C illustrates an example of an access procedure containing two steps associated with aspects of the present disclosure.

[0029] FIG. 1D illustrates an example of the 1-to-1 association between ROs and SSBs associated with aspects of the present disclosure.

[0030] FIG. 1E illustrates an example of the N-to-1 association between SSBs and ROs associated with aspects of the present disclosure.

[0031] FIG. 1F illustrates an example of the 1-to-N association between SSBs and ROs associated with aspects of the present disclosure.

[0032] FIG. 1G illustrates an example of POs in a PF associated with aspects of the present disclosure.

[0033] FIG. 1H illustrates an example of a RA procedure with adaptative RACH resources associated with aspects of the present disclosure.

[0034] FIG. 2 illustrates an example signaling chart illustrating an example process that supports a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0035] FIG. 3 illustrates a first example of a RACH resource in accordance with aspects of the present disclosure.

[0036] FIG. 4 illustrates a second example of a RACH resource in accordance with aspects of the present disclosure.

[0037] FIG. 5 illustrates a third example of a RACH resource in accordance with aspects of the present disclosure.

[0038] FIG. 6 illustrates a fourth example of a RACH resource in accordance with aspects of the present disclosure.

[0039] FIG. 7 illustrates an example of a determination of a preamble index in accordance with aspects of the present disclosure.

[0040] FIG. 8 illustrates a first example of a RAR format in accordance with aspects of the present disclosure.

[0041] FIG. 9 illustrates a second example of a RAR format in accordance with aspects of the present disclosure.

[0042] FIGS. 10 and 11 illustrate examples of devices that support a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0043] FIGS. 12 and 13 illustrate examples of processors that support a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0044] FIG. 14 illustrates a flowchart of a method that supports a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0045] FIG. 15 illustrates a flowchart of a method that supports a PRACH preamble transmission for network energy saving in accordance with aspects of the present disclosure.

[0046] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0047] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein may be implemented in various manners other than the ones described below.

[0048] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0049] References in the present disclosure to "one embodiment," "an example embodiment," "an embodiment," "some embodiments," and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0050] It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0051] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0052] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as, 5G new radio (NR), Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT), and so on. Further, the communications between a user equipment and a network device in the communication network may be performed according to any suitable generation communication protocols, including but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth

generation (4G), 4.5G, the fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will also be future type communication technologies and systems in which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned systems.

[0053] As used herein, the term "network device" generally refers to a node in a communication network via which a user equipment can access the communication network and receive services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), a radio access network (RAN) node, an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), an infrastructure device for a V2X (vehicle-to-everything) communication, a transmission and reception point (TRP), a reception point (RP), a remote radio head (RRH), a relay, an integrated access and backhaul (IAB) node, a low power node such as a femto BS, a pico BS, and so forth, depending on the applied terminology and technology. The network device may further refer to a network function (NF) in the core network, for example, a SMF, an AMF, a PCF, a UPF or devices with same function in future network architectures, and so forth.

[0054] As used herein, the term "user equipment (UE)" generally refers to any end device that may be capable of wireless communications. By way of example rather than a limitation, a user equipment may also be referred to as a communication device, a terminal device, an end user device, a subscriber station (SS), an unmanned aerial vehicle (UAV), a portable subscriber station, a mobile station (MS), or an access terminal (AT). The user equipment may include, but is not limited to, a mobile phone, a cellular phone, a smart phone, a voice over IP (VoIP) phone, a wireless local loop phone, a tablet, a wearable user equipment, a personal digital assistant (PDA), a portable computer, a desktop computer, an image capture user equipment such as a digital camera, a gaming user equipment, a music storage and playback appliance, a vehicle-mounted wireless user equipment, a wireless endpoint, a mobile station, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), a USB dongle, a smart device, wireless customer-premises equipment (CPE), an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device (for example, a remote surgery device), an industrial device (for example, a robot and/or other wireless

devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms: "user equipment," "communication device," "terminal," "user equipment" and "UE," may be used interchangeably.

[0055] FIG. 1A illustrates an example of a wireless communications system 100A that supports store and forward operations in accordance with aspects of the present disclosure. The wireless communications system 100A may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100A may support various radio access technologies. In some implementations, the wireless communications system 100A may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100A may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100A may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100A may support radio access technologies beyond 5G. Additionally, the wireless communications system 100A may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0056] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100A. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0057] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging,

broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0058] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100A. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100A. In some other implementations, a UE 104 may be mobile in the wireless communications system 100A.

[0059] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1A. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1A. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100A.

[0060] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0061] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0062] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0063] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP).

One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0064] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0065] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0066] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link

may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0067] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0068] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0069] In the wireless communications system 100A, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100A (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations,

such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0070] One or more numerologies may be supported in the wireless communications system 100A, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0071] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0072] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100A. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM

symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0073] In the wireless communications system 100A, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100A may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0074] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0075] A RACH procedure may be a so-called 4-step RACH procedure. As shown in FIG. 1B, the UE firstly transmits a Msg1 preamble in a valid RACH occasion (RO) of a PRACH slot to the BS, then receives a RAR in Msg2. The RAR indicates a reception of

the preamble and provides necessary information for the transmissions of Msg3 and Msg4. Msg3 and Msg4 are used to solve potential collisions due to simultaneous transmissions of the same preamble from different UEs. This RACH procedure is also called a contention based random access procedure since RACH preambles are not uniquely allocated to UEs but are open for UEs to select. As a comparison, for a UE in a radio resource control (RRC) CONNECTED state, as it has already connected to a cell, a unique RACH preamble can be configured for the UE to perform random access. This random access procedure contains only two steps and is a contention free procedure (also called contention free RACH procedure). As shown in FIG. 1C, the UE firstly transmits a Msg1 preamble, then receives a RAR in Msg2.

[0076] For Msg2, the medium access control (MAC) protocol data units (PDUs) for contention based RACH procedure and contention free RACH procedure are different. The MAC PDU for contention based RACH procedure contains MAC header, which includes a RAPID, and the MAC PDU contains a TA command, a UL grant for scheduling Msg3 and a temporary C-RNTI (TC-RNTI). The TC-RNTI would be turn to C-RNTI, if collision handling is successful. The MAC PDU for contention free RACH procedure contains a MAC header.

[0077] RACH msg1 preamble is transmitted in RACH occasions (ROs). The ROs are associated with SSBs that may be transmitted with different beams. The SSBs consists of primary synchronization signal (PSS)/ secondary synchronization signal (SSS) and physical broadcast channel (PBCH) for the UE to synchronize to the DL, obtain the cell identity (ID), and acquire the system information. The UE may measure the channel status of each SSB, select an SSB with good channel quality, and transmit a preamble in a RO that is associated with the SSB. The indexes of available SSBs can be obtained in the system information.

[0078] The association of SSBs (or beams) and ROs could be 1-to-1, 1-to-N, or N-to-1 depending on network configuration. FIGS. 1D, 1E and 1F illustrate examples for each type of association, where 8 SSBs (SSB#0~ SSB#7) are assumed, and N=2 is assumed for FIG. 1E and FIG. 1F. For 1-to-1 association between ROs and SSBs as shown in FIG. 1D and N-to-1 association between SSBs and ROs as shown in FIG. 1E, there is one RO in frequency domain. For 1-to-N association between SSBs and ROs as shown in FIG. 1F, there are 2 ROs in frequency domain.

[0079] For N-to-1 association, an available set of preambles in each RO are divided to be subsets and each subset of preambles are associated with an associated SSB. For example, in FIG. 1E, a subset of preambles of RO#1 is associated with an associated SSB#2, and another subset of preambles of RO#1 is associated with an associated SSB#3. Besides, in FIG. 1D, RO#0 to RO#7 are comprised in an SSB to RO mapping cycle, while in FIG. 1E, RO#0 to RO#3 form one SSB to RO mapping cycle and RO#4 to RO#7 form another SSB to RO mapping cycle. In FIG. 1F, RO#0, RO#2, RO#4, RO#6,RO#8, RO#10, RO#12 and RO#14 are comprised in an SSB to RO mapping cycle, and RO#1, RO#3, RO#5, RO#7,RO#9, RO#11, RO#13 and RO#15 form another SSB to RO mapping cycle. In an SSB to RO mapping cycle, each SSB maps to an RO once.

[0080] For both LTE and NR, the BS pages a UE when DL data arrives for the UE. The BS transmits a paging message when page the UEs, and the paging message may contain at least one paging record, and each paging record targets for a paged UE. The paging massage is transmitted in a paging occasion (PO). A PO is contained in a paging frame (PF). One or multiple PFs are contained in a configured paging cycle.

[0081] In NR, a PO contains at least one paging monitoring occasions, each of which is used to transmit paging DCI using a specific beam (i.e., associated with an SSB). FIG. 1G illustrates an example of POs in a PF associated with aspects of the present disclosure. As shown in FIG. 1G, one paging cycle contains two PFs and one PF contains two POs. A PO contains four PDCCH monitoring occasions, which is one-to-one associated with a beam.

[0082] In addition, adaptative RACH resources is use to achieve network energy saving (NES). The solution of adaptative RACH resources is to have a long periodicity PRACH resource which is always on, and a dynamically triggered additional PRACH resource when needed. The additional PRACH resource is used when the UE receives a paging message indicating the DL data arrival. The UE may start the RA procedure in the additional RACH resource when receives paging message without waiting and starting the RACH procedure in the always onRACH resource. As shown in FIG. 1H, at 130, the UE in an RRC INACTIVE state or RRC IDLE state receives paging message indicating the DL data arrival. At 140, the UE triggers additional PRACH resource for a RA procedure. At 150, the UE performs the RA procedure in the additional RACH resource (also called paging triggered RACH procedure). At 160, the UE performs a data

transmission. It can be seen that the solution of adaptative RACH resources is beneficial in terms of latency reduction.

[0083] In order to reduce the whole latency and enhance network energy saving, the paging triggered RACH procedure may be further optimized. The above mentioned contention free random access procedure may be used for the paging triggered random access procedure.

[0084] In view of the above discussions, some embodiments of the present disclosure provide a solution for PRACH preamble transmission, for example, for network energy saving. In one aspect of the solution of the present disclosure, a user equipment receives a paging message from a base station. The user equipment transmits a PRACH preamble transmission in a RACH resource to the base station. The RACH resource comprises at least one mapping cycle of at least one SSB to at least one RO. In this way, the user equipment may perform the PRACH preamble transmission in the RACH resource and the contention free random access procedure or contention based random access procedure may be used. Therefore, the network energy saving is improved. Principles and implementations of embodiments of the present disclosure will be described in detail below with reference to FIGS. 2-15.

[0085] FIG. 2 illustrates a signaling chart illustrating an example process 200 in accordance with aspects of the present disclosure. The process 200 may involve the user equipment 201 and the base station 202. It would be appreciated that although the process 200 is applied in the communication environment 100A of FIG. 1A, this process may be likewise applied to other communication scenarios with similar issues.

[0086] In the process 200, the base station 202 transmits 210 a paging message 215 to the user equipment 201. The user equipment 201 may be a UE in an RRC IDLE/INACTIVE state. A contention free random access procedure or a contention based random access procedure may be introduced for the UE in an RRC IDLE/INACTIVE state to resume the connection to the network or to access the network. The process 200 is performed by the user equipment 201 for paging triggered random access. Here paging triggered random access means that the process 200 is started in response of the paging message 215.

[0087] After receiving 220 the paging message 215 from the base station 202, the user equipment 201 transmits 225 a PRACH preamble transmission 230 in a RACH

resource to the base station 202. The RACH resource comprises at least one mapping cycle of at least one SSB to at least one RO. On the other side of the communication, the base station 202 receives 235 the PRACH preamble transmission 230 in the RACH resource from the user equipment 201. As another embodiment, the RACH resource may comprise at least one SSB to RO association period, where each period contains at least one SSB to RO mapping cycle.

[0088] From the user equipment 201 point of view, the UE may use a contention based random access procedure in the RACH resource. Moreover, a contention free random access may be achieved by determining a preamble by the user equipment 201 and transmitting the preamble in a determined RO without colliding with other UEs. That is, in the determined RO, the preamble is dedicated used by the user equipment 201 and is not available for other UEs. From system point of view, it should provide the RACH resource to guarantee that each paged UE can determine a unique preamble in the RACH resource for contention free random access. Therefore, a paged UE may firstly determine a RACH resource for random access, and the RACH resource may provide enough preambles for contention free random access for the paged UEs. As one embodiment, where contention based random access procedure or contention random access procedure is used is based on a configuration.

[0089] In some embodiments, the RACH resource may be configured by a paging DCI. Alternatively or additionally, the RACH resource may be configured by a paging record. In addition, the RACH resource may be configured by a paging message. Additionally, the RACH resource may be configured by a paging early indication (PEI). In some embodiments, the RACH resource may be triggered by a paging DCI. Alternatively or additionally, the RACH resource may be triggered by a paging record. In addition, the RACH resource may be triggered by a paging message. Additionally, the RACH resource may be triggered by a PEI. Here a triggered RACH resource means that the resources has already been configured, but it is enabled based on triggering.

[0090] For example, Msg1 is transmitted in the RACH resource. The RACH resource may be triggered or configured by a paging signalling, including either of a paging DCI, a paging record/message or a paging early indication (PEI).

[0091] Alternatively or additionally, the number of the at least one mapping cycle for contention based random access procedure may be determined based on at least one of a

number of supported paged UEs of the paging message in a PO, a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource. The PO associated with the RACH resource means that UEs being paged in this PO may start a contention free random access (CFRA) procedure in the associated RACH resource.

[0092] As mentioned, the RACH resource should contain enough ROs and preambles for the paged UEs to perform CFRA. Since the number of paged UEs might be varying in time, the number of ROs and preambles in the RACH resource should support maximum number of associated paged UEs (i.e., supported paged UEs) to perform the CFRA. Such number of UEs is determined by the number of POs that are associated with the RACH resource and the maximum number of paging records of a paging message that is transmitted in the PO (e.g., 32 paging records per PO as in NR). As one embodiment, for CBRA, the number of mapping cycles or the number of SSB to RO association periods in the RACH resource based on determined based on a configuration.

[0093] For example, the supported maximum number of paged UEs of the RACH resource is equal to $N_PO \times N_pagingRecordPerPO$. N_PO is the number of POs associated with the RACH resource, and N_pagingRecordPerPO is the maximum number of paging records that can be transmitted per PO (i.e., included a paging message). In an example, N_PO may be always equal to 1, which means different POs are associated with different RACH resources.

[0094] With the above number of paged UEs, the number of ROs in the RACH resource may be determined. Since ROs are associated with beams (or SSBs), then for each beam, the number of preambles in the RACH resource should at least equal to the number of paged UEs. This leads to the requirement of determining the number of mapping cycles of at least one SSB to at least one RO in the RACH resource.

[0095] Depending on an association between at least one SSB with at least one RO, one RO may provide different number of preambles for a beam(or SSB). For example, for 1-to-1 SSB to RO association, the number of preambles of a RO for the associated SSB/beam may be n_preamblePerRO (e.g., 64 preambles per RO as in NR). For N SSBs associated with one RO, the number of preambles of a RO for each associated SSB/beam may be n_preamblesPerSSB = n_preamblePerRO/N_SSB, and N_SSB is the number of SSBs. It can be seen that such SSB to RO association is a factor to determine the number

of ROs or the number of mapping cycles of SSB to RO in the paging triggered or configured RACH resource.

[0096] Therefore, the number of mapping cycles of at least one SSB to at least one RO or the ROs in the RACH resource in the RACH resource may be determined by at least one of the number of supported paged UEs in a paging message, the number of POs associated with the RACH resource, and the association between at least one SSB with at least one RO for the RACH resource.

[0097] For the association between at least one SSB with at least one RO, if one SSB is associated with one or more ROs, the user equipment 201 may determine the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, and a number of preambles of a RO.

[0098] As one embodiment, for 1-to-N SSB to RO association, and N is greater than or equal to1, the paging triggered RACH resource should contain N_cycle mapping cycles. The number of the at least one mapping cycle may be determined as following:

$$N_cycle = ceil\ [(N_POs * N_records)/N_preambles] \quad (1)$$

[0099] N_cycle is the number of the at least one mapping cycle, N_POs is the number of POs associated with the additional RACH resources, N_records is the maximum number of paging records in a paging message is (e.g., 32 paging records per paging message as in NR), and N_preambles is the number of available preambles of an RO.

[0100] FIG. 3 illustrates a first example of a RACH resource in accordance with aspects of the present disclosure. As shown in FIG. 3, a RACH resource is associated with one PO (PO#0). The network has 4 actually transmitted SSBs (SSB#0, SSB#1, SSB#2 and SSB#3), so one PO contains 4 paging monitoring occasions, each transmitted with a specific beam. The paging message transmitted in each beam is same. As shown in FIG. 3, an SSB is associated with a RO, then the number of preambles a RO can provide for the associated beam is 64. Since one mapping cycle in can provide enough number of preambles for the paged UEs in the associated PO, the RACH resource contains one mapping cycle.

[0101] FIG. 4 illustrates a second example of a RACH resource in accordance with aspects of the present disclosure. As shown in FIG. 4, a RACH resource is associated

with one PO (PO#0). The network has 4 actually transmitted SSBs (SSB#0, SSB#1, SSB#2 and SSB#3), so one PO contains 4 paging monitoring occasions, each transmitted with a specific beam. The paging message transmitted in each beam is same. As shown in FIG. 3, 2 SSBs are associated with 1 RO, then the number of preambles a RO can provide for the associated beam is 64/2 = 32. Since one mapping cycle in can provide enough number of preambles for the paged UEs in the associated PO, the RACH resource contains one mapping cycle.

[0102] FIG. 5 illustrates a third example of a RACH resource in accordance with aspects of the present disclosure. As shown in FIG. 5, the RACH resource is associated with two POs, and an SSB is associated with a RO. The number of preambles in a RO can provide for the associated beam is 64, which can provide enough number of preambles for the paged UEs in the two associated POs. The RACH resource contains one mapping cycle.

[0103] Alternatively, if multiple SSBs are associated with one RO, the user equipment 201 may determine the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, a number of preambles of a RO, and a number of the multiple SSBs.

[0104] As another embodiment, for N-to-1 SSB to RO association, N is less than 1, the number of the at least one mapping cycle may be determined as following:

$$N_cycle = (N_POs * N_records * N)/N_preambles \quad (2)$$

[0105] The meanings of the parameters are the same as that of equation (1).

[0106] FIG. 6 illustrates a fourth example of a RACH resource in accordance with aspects of the present disclosure. As shown in FIG. 6, a RACH resource is associated with two POs, and 2 SSBs are associated with a RO, so the number of preambles a RO can provide for the associated beam is 64/2 = 32. Here the mapping cycles of two SSBs to one RO are needed to provide enough number of preambles for the paged UEs in the associated PO, so the RACH resource contains two mapping cycles.

[0107] Alternatively or additionally, the user equipment 201 may further determine a RO among one or more ROs of a mapping cycle for the PRACH preamble transmission 230 based on an association between the at least one PO and the at least one mapping

cycle. The association of at least one PO and at least one mapping cycle means that a UE receiving a paging record in a PO will start a CFRA in a RO of the PO associated mapping cycle of at least one SSB to at least one RO. From the determined association between the at least one SSB and the at least one RO in the RACH resource, the association of a PO and a mapping cycle can be determined. The RO may be determined after determining the mapping cycle for the PRACH preamble transmission.

[0108] In some embodiments, the association between the at least one PO and the at least one mapping cycle may be based on indexed POs associated with a same PRACH resource and indexed mapping cycles of the PRACH resource.

[0109] In the first example, if a first number of the at least one PO is equal to a second number of the at least one mapping cycle, a PO may be associated with a RO with the same index. For example, supposing M POs are associated with a RACH resource, which contains N SSB to RO mapping cycle. The user equipment 201 determines the target RO or a target mapping cycle of at least one SSB to at least one RO based on the association of the POs and mapping cycles of SSBs to ROs. If M is equal to N, the PO and the mapping cycle is one-to-one associated. Then the PO and the RO may have the same index. In addition, the PO and the mapping cycle may have the same index. As shown in FIGS. 3 and 4, the PO and the mapping cycle is one-to-one associated. PO#0 and mapping cycle#0 have the same index.

[0110] In the second example, if a first number of the at least one PO is equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs may be associated with a RO with the same index, and a number of POs in the set of POs is equal to the third number. In addition, an index of a set of POs may be associated with a mapping cycle with the same index. For example, if M = k* N and k is greater than 1, k POs are associated with one mapping cycle. The first k POs may be associated with the first mapping cycle of at least one SSB to at least one RO, the second k POs may be associated with the second mapping cycle of at least one SSB to at least one RO, and so on. As shown in FIG. 5, the POs and the mapping cycle is two-to-one associated, and PO#0 and PO#1is associated with mapping cycle#0, i.e., the first two POs is associated with the first mapping cycle. As shown in FIG. 6, PO#0 is associated with mapping cycle #0 in the RACH resource, and PO#1 is associated with mapping cycle #1.

[0111] In the third example, if a second number of the at least one mapping cycle is equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO may be associated with a RO with the same index, and a number of paging records in the set of paging records is equal to a number of paging records in a PO divided by the fourth number. For example, if k*M = N, k is greater than 1, N_pagingRecord/k paging records of a paging message in a PO are associated with one mapping cycle of at least one SSB to at least one RO. The first N_pagingRecord/k paging recodes of the PO are associated with the first mapping cycle, the second N_pagingRecord/k paging records are associated with the second mapping cycle, and so on. N_pagingRecord is the number of paging records in a PO.

[0112] Alternatively or additionally, the user equipment 201 may further determine a preamble of the PRACH preamble transmission 230 based on a preamble start index and a paging record index. Regarding the RACH preamble determination for CFRA, the user equipment 201 may determine a preamble based on at least a configured or a predefined preamble start index.

[0113] As one embodiment, if one SSB is associated with one or more ROs, the user equipment 201 may determine an index of the preamble based on the preamble start index, the paging record index, and a number of preambles of a RO. For instance, in the determined RO of the determined SSB to RO mapping cycle, if SSB to RO is 1-to-N associated, the user equipment 201 may determine the preamble with the index:

preambleIndex = mod (preambleStartIndex + pagingRecordIndex, N_Preambles) (3)

where preambleIndex is the index of the preamble, preambleStartIndex is the index of the first preamble for the preamble set in the RO, i.e., the preamble start index, and pagingRecordIndex is the index of the paging record in the paging message, N_Preamble is the number of preambles in an RO.

[0114] As shown in FIG. 7, PO#m is associated with ROs in mapping cycle #n, and the preamble start index is 3. For a UE, assuming the paging record (PR) index is 1 in the received paging message, then the preamble index can be determined as mod (3+1, 64) = 4, i.e., PI#4.

[0115] As another embodiment, if multiple SSBs are associated with one RO, the user equipment 201 may determine an index of the preamble based on the preamble start index,

an index of a first preamble among a set of preambles associated with the multiple SSBs, the paging record index, and a number of preambles of an SSB in a RO. For instance, in the determined RO of the determined SSB to RO mapping cycle, if SSB to RO is N-to-1 associated, the user equipment 201 determines the preamble with index:

preambleIndex=mod(preambleStartIndex+preambleStartIndexSSB+pagingRecordIndex, N_PreambleSSB) (4)

where preambleStartIndexSSB is index of the first preamble for the preamble set that is associated with the SSB. N_PreambleSSB is the number of preambles that are available for an SSB in an RO.

[0116] The configuration for the preamble start index, if provided, can be through either of an RRC/MAC/PHY signalling. In a first example, the preamble start index may be configured via a radio resource control (RRC) message. In a second example, the preamble start index may be configured via a medium access control (MAC) message. In a third example, the preamble start index may be configured via a physical layer message. In addition, the preamble start index may be predefined.

[0117] In order to transmit the PRACH preamble transmission 230, the user equipment 201 may transmit the preamble to the base station 202 on the determined RO. Correspondingly, the base station 202 may receive the preamble of the PRACH preamble transmission 230 from the user equipment 201

[0118] Alternatively or additionally, the base station 202 may transmit a RAR for the PRACH preamble transmission 230 to the user equipment 201 after receiving the preamble. Correspondingly, the user equipment 201 may further receive a RAR for the PRACH preamble transmission 230 from the base station 202 after transmitting the preamble. Then the user equipment 201 may stop the RA procedure.

[0119] In some embodiments, the RAR may comprise a TA command and a C-RNTI. The RAR format for the proposed CFRA is a new one and is different with that in common CFRA, which contains TA command, the UL-grant for scheduling msg3 and the temporary C-RNTI (TC-RNTI). The new RAR does not need to contain UL-grant, since Msg3 will not be transmitted in the proposed CFRA procedure. Besides, TC-RNTI is not needed since there is collision handling procedure, so it is replaced with C-RNTI. Based

on these, the new RAR format may contain TA command and C-RNTI, as shown in FIG. 8.

[0120] In some other embodiments, the RAR may comprise a TA command, a C-RNTI, and a DL grant for scheduling a transmission of an RRC setup message or an RRC resume message. Besides the TA command and C-RNTI, the new RAR may further contain an DL-grant, which is used for scheduling RRC setup message or RRC resume message, as shown in FIG. 9. The RRC setup message and RRC resume message are corresponds to the first UE specific RRC message when the user equipment 201 switches to RRC CONNECTED state.

[0121] In general, contention free random access procedure triggered paging is proposed. A paged UE determine a RACH resource for the random access firstly, and the RACH resource can provide enough preambles for contention free random access for the paged UEs. Then the UE determines a RO in the RACH resource and lastly determine a unique preamble to be transmitted in the determined RO.

[0122] For RACH resource determination, the ROs in the RACH resource or the number of mapping cycles of SSBs to ROs in the RACH resource is determined by at least one of the number of supported paged UEs in a paging message, the number of associated POs, and the SSB to RO association for the RACH resource. For RO determination, UE determines the target PO or target mapping cycle of SSB to RO based on the association of the POs and mapping cycles of SSBs to ROs. For the preamble determination, the UE determines a CFRA preamble based on at least a configured or a predefined preamble start index and the paging record index.

[0123] In addition, two RAR formats are proposed for the CFRA procedure. RAR format 1 contains a TA command and a C-RNTI. RAR format 2 contains a TA command, a C-RNTI and a DL-grant, where DL-grant is used for schedule RRC setup or RRC resume message.

[0124] FIG. 10 illustrates an example of a device 1000 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The device 1000 may be an example of a UE 104 as described herein. The device 1000 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 1000 may include components for bi-directional communications including components for transmitting and receiving communications,

such as a processor 1002, a memory 1004, a transceiver 1006, and, optionally, an I/O controller 1008. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0125] The processor 1002, the memory 1004, the transceiver 1006, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 1002, the memory 1004, the transceiver 1006, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0126] In some implementations, the processor 1002, the memory 1004, the transceiver 1006, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 1002 and the memory 1004 coupled with the processor 1002 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 1002, instructions stored in the memory 1004).

[0127] For example, the processor 1002 may support wireless communication at the device 1000 in accordance with examples as disclosed herein. The processor 1002 may be configured to operable to support a means for receiving, via the transceiver from a base station, a paging message, and means for transmitting, via the transceiver to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The processor 1002 may be configured to operable to support other means for other implementations of method 1400.

[0128] The processor 1002 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a

programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 1002 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 1002. The processor 1002 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 1004) to cause the device 1000 to perform various functions of the present disclosure.

[0129] The memory 1004 may include random access memory (RAM) and read-only memory (ROM). The memory 1004 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1002 cause the device 1000 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 1002 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 1004 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0130] The I/O controller 1008 may manage input and output signals for the device 1000. The I/O controller 1008 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 1008 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 1008 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 1008 may be implemented as part of a processor, such as the processor 1006. In some implementations, a user may interact with the device 1000 via the I/O controller 1008 or via hardware components controlled by the I/O controller 1008.

[0131] In some implementations, the device 1000 may include a single antenna 1010. However, in some other implementations, the device 1000 may have more than one antenna 1010 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 1006 may communicate bi-directionally, via the one or

more antennas 1010, wired, or wireless links as described herein. For example, the transceiver 1006 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 1006 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 1010 for transmission, and to demodulate packets received from the one or more antennas 1010. The transceiver 1006 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0132] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 1010 for transmitting the amplified signal into the air or wireless medium.

[0133] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 1010 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0134] FIG. 11 illustrates an example of a device 1100 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The device 1100 may be an example of a network entity 102 as described herein. The device 1100 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 1100 may include components for bi-directional communications including components for transmitting and receiving communications,

such as a processor 1102, a memory 1104, a transceiver 1106, and, optionally, an I/O controller 1108. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0135] The processor 1102, the memory 1104, the transceiver 1106, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 1102, the memory 1104, the transceiver 1106, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0136] In some implementations, the processor 1102, the memory 1104, the transceiver 1106, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 1102 and the memory 1104 coupled with the processor 1102 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 1102, instructions stored in the memory 1104).

[0137] For example, the processor 1102 may support wireless communication at the device 1100 in accordance with examples as disclosed herein. The processor 1102 may be configured to operable to support a means for transmitting, via the transceiver to a user equipment (UE), a paging message, and means for receiving, via the transceiver from the UE, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The processor 1102 may be configured to operable to support other means for other implementations of method 1500.

[0138] The processor 1102 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a

programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 1102 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 1102. The processor 1102 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 1104) to cause the device 1100 to perform various functions of the present disclosure.

[0139] The memory 1104 may include random access memory (RAM) and read-only memory (ROM). The memory 1104 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1102 cause the device 1100 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 1102 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 1104 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0140] The I/O controller 1108 may manage input and output signals for the device 1100. The I/O controller 1108 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 1108 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 1108 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 1108 may be implemented as part of a processor, such as the processor 1106. In some implementations, a user may interact with the device 1100 via the I/O controller 1108 or via hardware components controlled by the I/O controller 1108.

[0141] In some implementations, the device 1100 may include a single antenna 1110. However, in some other implementations, the device 1100 may have more than one antenna 1110 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 1106 may communicate bi-directionally, via the one or

more antennas 1110, wired, or wireless links as described herein. For example, the transceiver 1106 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 1106 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 1110 for transmission, and to demodulate packets received from the one or more antennas 1110. The transceiver 1106 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0142] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 1110 for transmitting the amplified signal into the air or wireless medium.

[0143] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 1110 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0144] FIG. 12 illustrates an example of a processor 1200 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The processor 1200 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1200 may include a controller 1202 configured to perform various operations in accordance with examples as described herein. The processor 1200 may optionally include at least one memory 1204.

Additionally, or alternatively, the processor 1200 may optionally include one or more arithmetic-logic units (ALUs) 1200. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0145] The processor 1200 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1200) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0146] The controller 1202 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1200 to cause the processor 1200 to support various operations in accordance with examples as described herein. For example, the controller 1202 may operate as a control unit of the processor 1200, generating control signals that manage the operation of various components of the processor 1200. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0147] The controller 1202 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1204 and determine subsequent instruction(s) to be executed to cause the processor 1200 to support various operations in accordance with examples as described herein. The controller 1202 may be configured to track memory address of instructions associated with the memory 1204. The controller 1202 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1202 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1200 to cause the processor 1200 to support various operations in accordance

with examples as described herein. Additionally, or alternatively, the controller 1202 may be configured to manage flow of data within the processor 1200. The controller 1202 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 1200.

[0148] The memory 1204 may include one or more caches (e.g., memory local to or included in the processor 1200 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 1204 may reside within or on a processor chipset (e.g., local to the processor 1200). In some other implementations, the memory 1204 may reside external to the processor chipset (e.g., remote to the processor 1200).

[0149] The memory 1204 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1200, cause the processor 1200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 1202 and/or the processor 1200 may be configured to execute computer-readable instructions stored in the memory 1204 to cause the processor 1200 to perform various functions (e.g., functions or tasks supporting transmit power prioritization). For example, the processor 1200 and/or the controller 1202 may be coupled with or to the memory 1204, the processor 1200, the controller 1202, and the memory 1204 may be configured to perform various functions described herein. In some examples, the processor 1200 may include multiple processors and the memory 1204 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0150] The one or more ALUs 1200 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 1200 may reside within or on a processor chipset (e.g., the processor 1200). In some other implementations, the one or more ALUs 1200 may reside external to the processor chipset (e.g., the processor 1200). One or more ALUs 1200 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1200 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1200 be configured

with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1200 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1200 to handle conditional operations, comparisons, and bitwise operations.

[0151] The processor 1200 may support wireless communication in accordance with examples as disclosed herein. The processor 1202 may be configured to or operable to support a means for receiving, from a base station, a paging message; and means for transmitting, to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The processor 1200 may be configured to or operable to support other means for other implementations of method 1400.

[0152] FIG. 13 illustrates an example of a processor 1300 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The processor 1300 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1300 may include a controller 1302 configured to perform various operations in accordance with examples as described herein. The processor 1300 may optionally include at least one memory 1304. Additionally, or alternatively, the processor 1300 may optionally include one or more arithmetic-logic units (ALUs) 1300. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0153] The processor 1300 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1300) or other memory (e.g., random access memory (RAM), read-only memory (ROM),

dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0154] The controller 1302 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1300 to cause the processor 1300 to support various operations in accordance with examples as described herein. For example, the controller 1302 may operate as a control unit of the processor 1300, generating control signals that manage the operation of various components of the processor 1300. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0155] The controller 1302 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1304 and determine subsequent instruction(s) to be executed to cause the processor 1300 to support various operations in accordance with examples as described herein. The controller 1302 may be configured to track memory address of instructions associated with the memory 1304. The controller 1302 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1302 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1300 to cause the processor 1300 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 1302 may be configured to manage flow of data within the processor 1300. The controller 1302 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 1300.

[0156] The memory 1304 may include one or more caches (e.g., memory local to or included in the processor 1300 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 1304 may reside within or on a processor chipset (e.g., local to the processor 1300). In some other implementations, the memory 1304 may reside external to the processor chipset (e.g., remote to the processor 1300).

[0157] The memory 1304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1300, cause the processor 1300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 1302 and/or the processor 1300 may be configured to execute computer-readable instructions stored in the memory 1304 to cause the processor 1300 to perform various functions (e.g., functions or tasks supporting transmit power prioritization). For example, the processor 1300 and/or the controller 1302 may be coupled with or to the memory 1304, the processor 1300, the controller 1302, and the memory 1304 may be configured to perform various functions described herein. In some examples, the processor 1300 may include multiple processors and the memory 1304 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0158] The one or more ALUs 1300 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 1300 may reside within or on a processor chipset (e.g., the processor 1300). In some other implementations, the one or more ALUs 1300 may reside external to the processor chipset (e.g., the processor 1300). One or more ALUs 1300 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1300 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1300 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1300 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1300 to handle conditional operations, comparisons, and bitwise operations.

[0159] The processor 1300 may support wireless communication in accordance with examples as disclosed herein. The processor 1302 may be configured to or operable to support a means for transmitting, to a user equipment (UE), a paging message, and means for receiving, from the UE, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource

comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The processor 1300 may be configured to or operable to support other means for other implementations of method 1500.

[0160] FIG. 14 illustrates a flowchart of a method 1400 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The operations of the method 1400 may be implemented by a device or its components as described herein. For example, the operations of the method 1400 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0161] At 1405, the method may include receiving, from a base station, a paging message. The operations of 1405 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1405 may be performed by a device as described with reference to FIG. 1A.

[0162] At 1410, the method may include transmitting, to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The operations of 1410 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1410 may be performed by a device as described with reference to FIG. 1A.

[0163] In some embodiments, the number of the at least one mapping cycle may be determined based on at least one of a number of supported paged UEs of the paging message in a paging occasion (PO), a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource.

[0164] In some embodiments, the number of the at least one mapping cycle may be determined by in the case that one SSB is associated with one or more ROs, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH

resource, and a number of preambles of a RO, or in the case that multiple SSBs are associated with one RO, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, a number of preambles of a RO, and a number of the multiple SSBs.

[0165] In some embodiments, the method may further include determining a RO among one or more ROs of a mapping cycle for PRACH preamble transmission based on an association between the at least one PO and the at least one mapping cycle.

[0166] In some embodiments, the association between the at least one PO and the at least one mapping cycle may be based on indexed POs associated with a same PRACH resource and indexed mapping cycles of the PRACH resource.

[0167] In some embodiments, in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle, a PO is associated with a RO with the same index, in the case that a first number of the at least one PO is equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs may be associated with a RO with the same index, wherein a number of POs in the set of POs is equal to the third number, or in the case that a second number of the at least one mapping cycle may be equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO is associated with a RO with the same index, wherein a number of paging records in the set of paging records is equal to a number of paging records in a PO divided by the fourth number.

[0168] In some embodiments, the method may further include determining a preamble of the PRACH preamble transmission based on a preamble start index and a paging record index.

[0169] In some embodiments, the method may further include determining the preamble by: in the case that one SSB is associated with one or more ROs, determining an index of the preamble based on the preamble start index, the paging record index, and a number of preambles of a RO, and in the case that multiple SSBs are associated with one RO, determining an index of the preamble based on the preamble start index, an index of a first preamble among a set of preambles associated with the multiple SSBs, the paging record index, and a number of preambles of an SSB in a RO.

[0170] In some embodiments, the preamble start index may be configured via a radio resource control (RRC) message, the preamble start index may be configured via a medium access control (MAC) message, the preamble start index may be configured via a physical layer message, the preamble start index may be predefined.

[0171] In some embodiments, the method may further include transmitting the PRACH preamble transmission by: transmitting, via the transceiver to the base station, the preamble on the determined RO.

[0172] In some embodiments, the method may further include receiving, from the base station, a random access response (RAR) for the PRACH preamble transmission after transmitting the preamble, and stopping a random access (RA) procedure.

[0173] In some embodiments, the RAR may comprise a timing advance (TA) command and a cell radio network temporary identifier (C-RNTI), or the RAR may comprise a TA command, a C-RNTI, and a downlink (DL) grant for scheduling a transmission of an RRC setup message or an RRC resume message.

[0174] In some embodiments, the RACH resource may be configured by a paging downlink control information (DCI), the RACH resource may be configured by a paging record, the RACH resource may be configured by a paging message, the RACH resource may be configured by a paging early indication (PEI), the RACH resource may be triggered by a paging DCI, the RACH resource may be triggered by a paging record, the RACH resource may be triggered by a paging message, or the RACH resource may be triggered by a PEI.

[0175] FIG. 15 illustrates a flowchart of a method 1500 that supports a PRACH preamble transmission in accordance with aspects of the present disclosure. The operations of the method 1500 may be implemented by a device or its components as described herein. For example, the operations of the method 1500 may be performed by a network entity 102 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0176] At 1505, the method may include transmitting a paging message to a user equipment (UE). The operations of 1505 may be performed in accordance with examples

as described herein. In some implementations, aspects of the operations of 1505 may be performed by a device as described with reference to FIG. 1A.

[0177] At 1510, the method may include receiving a physical random access channel (PRACH) preamble transmission from the UE in a random access channel (RACH) resource, and the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO). The operations of 1510 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1510 may be performed by a device as described with reference to FIG. 1A.

[0178] In some embodiments, the number of the at least one mapping cycle may be determined based on at least one of a number of supported paged UEs of the paging message in a paging occasion (PO), a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource.

[0179] In some embodiments, in the case that one SSB may be associated with one or more ROs, the number of the at least one mapping cycle may be determined based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource and a number of preambles of a RO, or in the case that multiple SSBs are associated with one RO, the number of the at least one mapping cycle may be determined based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, a number of preambles of a RO and a number of the multiple SSBs.

[0180] In some embodiments, in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle, a PO may be associated with a RO with the same index; in the case that a first number of the at least one PO may be equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs may be associated with a RO with the same index, and a number of POs in the set of POs is equal to the third number; or in the case that a second number of the at least one mapping cycle may be equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO is associated with a RO with the same index, wherein a number of paging records in the

set of paging records is equal to a number of paging records in a PO divided by the fourth number.

[0181] In some embodiments, the method may further include receiving the PRACH preamble transmission by: receiving, from the UE, a preamble of the PRACH preamble transmission.

[0182] In some embodiments, the method may further include transmitting a random access response (RAR) to the UE for the PRACH preamble transmission after receiving the preamble.

[0183] In some embodiments, the RAR may comprise a timing advance (TA) command and a cell radio network temporary identifier (C-RNTI), or the RAR may comprise a TA command, a C-RNTI, and a downlink (DL) grant for scheduling a transmission of an RRC setup message or an RRC resume message.

[0184] In some embodiments, the RACH resource may be configured by a paging downlink control information (DCI), the RACH resource may be configured by a paging record, the RACH resource may be configured by a paging message, the RACH resource may be configured by a paging early indication (PEI), the RACH resource may be triggered by a paging DCI, the RACH resource may be triggered by a paging record, the RACH resource may be triggered by a paging message, or the RACH resource may be triggered by a PEI.

[0185] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0186] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple

microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0187] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0188] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0189] As used herein, including in the claims, an article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on

condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

[0190] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A user equipment (UE) comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive, via the transceiver from a base station, a paging message; and

transmit, via the transceiver to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, wherein:

the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

2. The UE of claim 1, wherein the number of the at least one mapping cycle is determined based on at least one of a number of supported paged UEs of the paging message in a paging occasion (PO), a number of at least one PO associated with the RACH resource, or an association between at least one SSB with at least one RO for the RACH resource.

3. The UE of claim 2, wherein the processor is configured to determine the number of the at least one mapping cycle by:

in the case that one SSB is associated with one or more ROs, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, and a number of preambles of a RO; or

in the case that multiple SSBs are associated with one RO, determining the number of the at least one mapping cycle based on the number of supported paged UEs in the paging message, a number of the at least one PO associated with the RACH resource, a number of preambles of a RO, and a number of the multiple SSBs.

4. The UE of claim 1, wherein the processor is further configured to:

determine a RO among one or more ROs of a mapping cycle for PRACH preamble transmission based on an association between the at least one PO and the at least one mapping cycle.

5. The method of claim 4, wherein the association between the at least one PO and the at least one mapping cycle is based on indexed POs associated with a same PRACH resource and indexed mapping cycles of the PRACH resource.

6. The method of claim 5, wherein one of the following:

in the case that a first number of the at least one PO is equal to a second number of the at least one mapping cycle, a PO is associated with a RO with the same index;

in the case that a first number of the at least one PO is equal to a second number of the at least one mapping cycle multiplied by a third number, an index of a set of POs is associated with a RO with the same index, wherein a number of POs in the set of POs is equal to the third number; or

in the case that a second number of the at least one mapping cycle is equal to a first number of the at least one PO multiplied by a fourth number, an index of a set of paging records in a PO is associated with a RO with the same index, wherein a number of paging records in the set of paging records is equal to a number of paging records in a PO divided by the fourth number.

7. The UE of claim 1, wherein the processor is further configured to:

determine a preamble of the PRACH preamble transmission based on a preamble start index and a paging record index.

8. The UE of claim 7, wherein the processor is configured to determine the preamble by:

in the case that one SSB is associated with one or more ROs, determining an index of the preamble based on the preamble start index, the paging record index, and a number of preambles of a RO; and

in the case that multiple SSBs are associated with one RO, determining an index of the preamble based on the preamble start index, an index of a first preamble among a

set of preambles associated with the multiple SSBs, the paging record index, and a number of preambles of an SSB in a RO.

9. The UE of claim 7, wherein one of the following:

the preamble start index is configured via a radio resource control (RRC) message;

the preamble start index is configured via a medium access control (MAC) message;

the preamble start index is configured via a physical layer message; or

the preamble start index is predefined.

10. The UE of claim 7, wherein the processor is configured to transmit the PRACH preamble transmission by:

transmitting, via the transceiver to the base station, the preamble on the determined RO.

11. The UE of claim 10, wherein the processor is further configured to:

receive, via the transceiver from the base station, a random access response (RAR) for the PRACH preamble transmission after transmitting the preamble; and

stop a random access (RA) procedure.

12. The UE of claim 11, wherein one of the following:

the RAR comprises a timing advance (TA) command and a cell radio network temporary identifier (C-RNTI); or

the RAR comprises a TA command, a C-RNTI, and a downlink (DL) grant for scheduling a transmission of an RRC setup message or an RRC resume message.

13. The UE of any of claims 1-12, wherein one of the following:

the RACH resource is configured by a paging downlink control information (DCI);

the RACH resource is configured by a paging record;

the RACH resource is configured by a paging message;

the RACH resource is configured by a paging early indication (PEI);

the RACH resource is triggered by a paging DCI;

the RACH resource is triggered by a paging record;

the RACH resource is triggered by a paging message; or

the RACH resource is triggered by a PEI.

14. A base station comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, via the transceiver to a user equipment (UE), a paging message; and

receive, via the transceiver from the UE, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, wherein:

the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

15. A method performed by a user equipment (UE), comprising:

receiving, from a first cell, a paging message; and

transmitting, to the base station, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, wherein:

the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

16. A method performed by a base station, comprising:

transmitting, to a user equipment (UE),a paging message; and

receiving, from the UE, a physical random access channel (PRACH) preamble transmission in a random access channel (RACH) resource, wherein:

the RACH resource comprises at least one mapping cycle of at least one synchronization signal and physical broadcast channel (SS/PBCH) block (SSB) to at least one RACH occasion (RO).

DRAWINGS

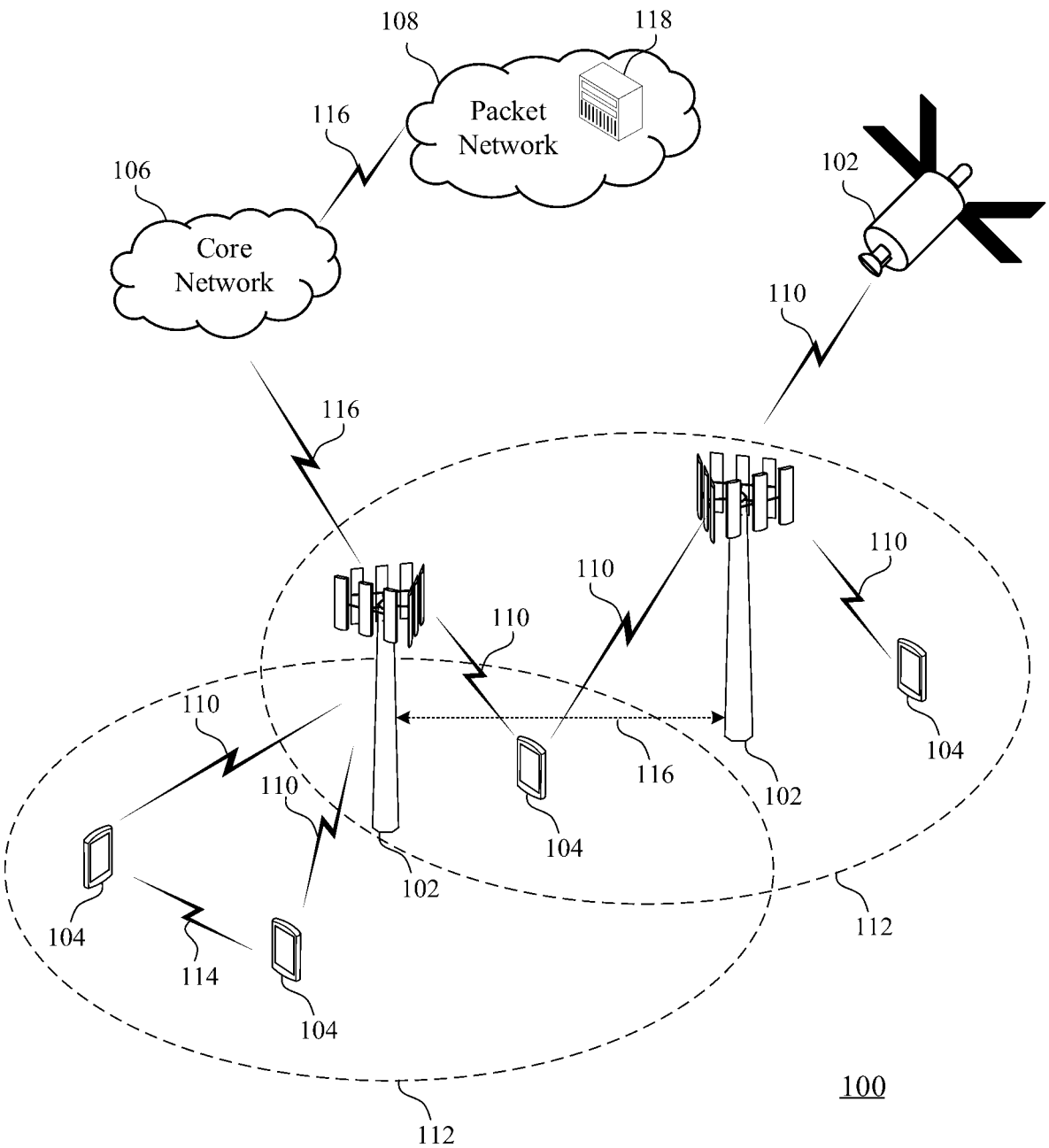

FIG. 1A

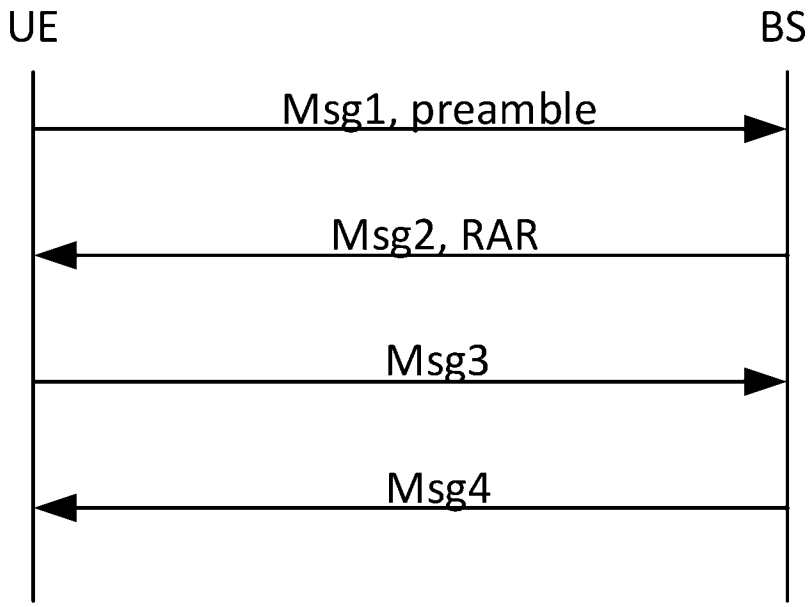
UE
BS
Msg1, preamble
Msg2, RAR
Msg3
Msg4

FIG. 1B

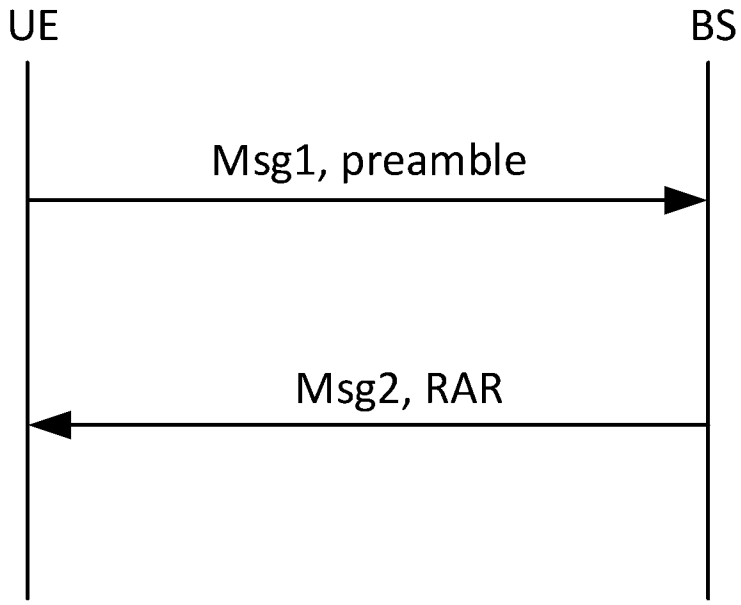
UE
BS
Msg1, preamble
Msg2, RAR

FIG. 1C

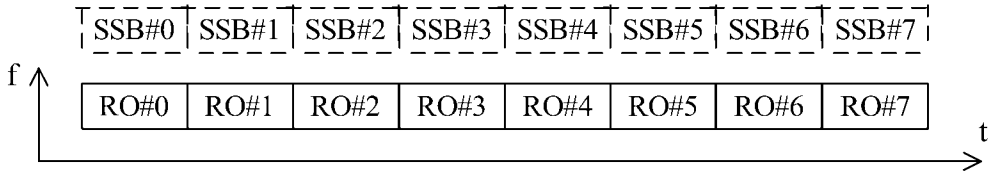

FIG. 1D

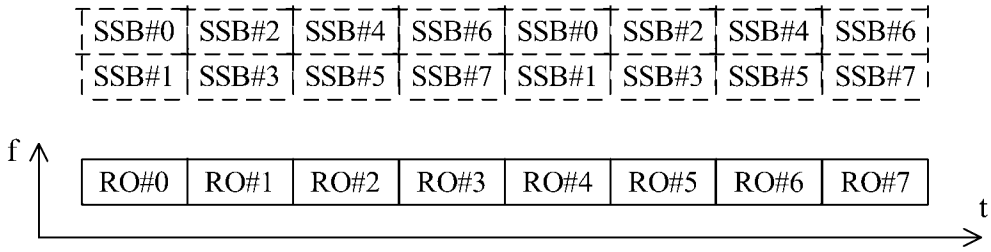

FIG. 1E

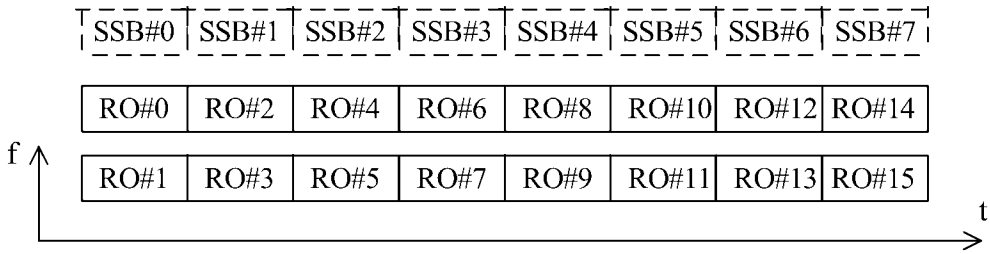

FIG. 1F

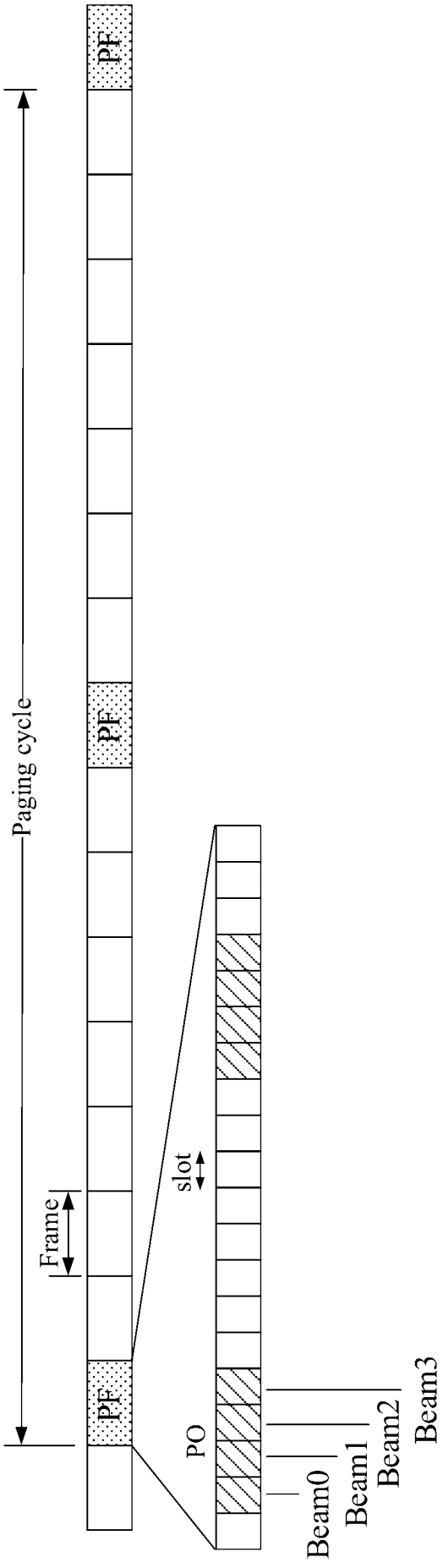

FIG. 1G

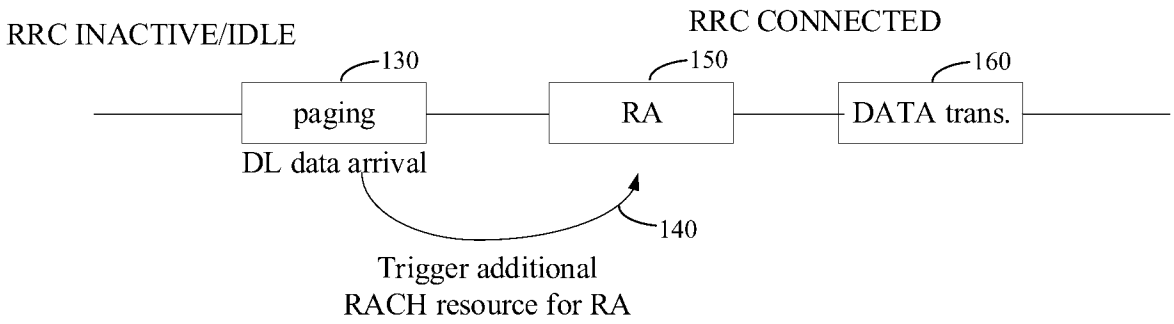
RRC INACTIVE/IDLE
RRC CONNECTED
130
150
160
paging
RA
DATA trans.
DL data arrival
140
Trigger additional
RACH resource for RA

FIG. 1H

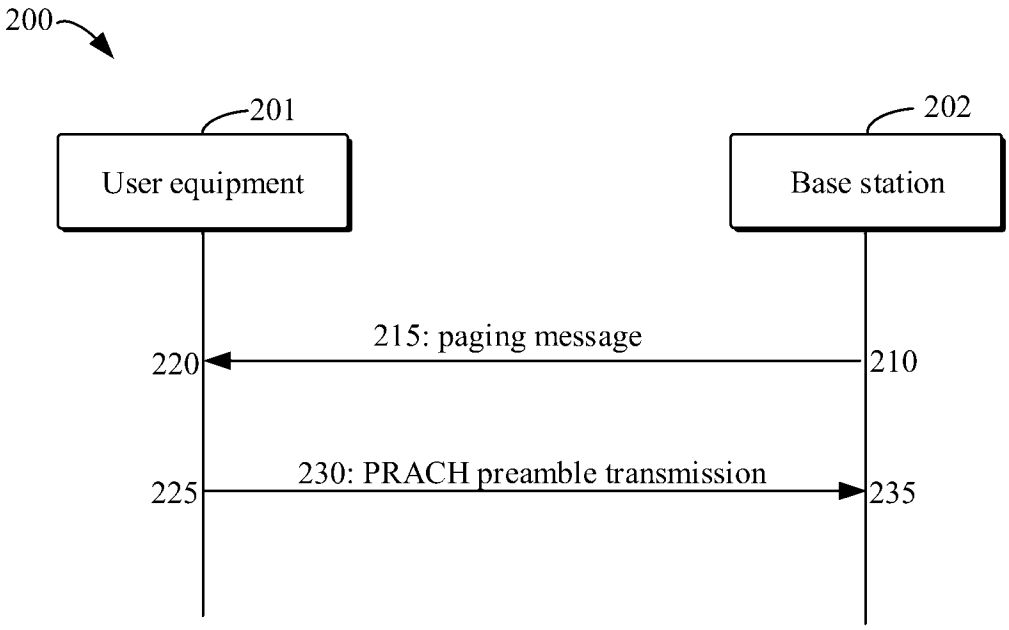
200
201
User equipment
202
Base station
215: paging message
220
210
230: PRACH preamble transmission
225
235

FIG. 2

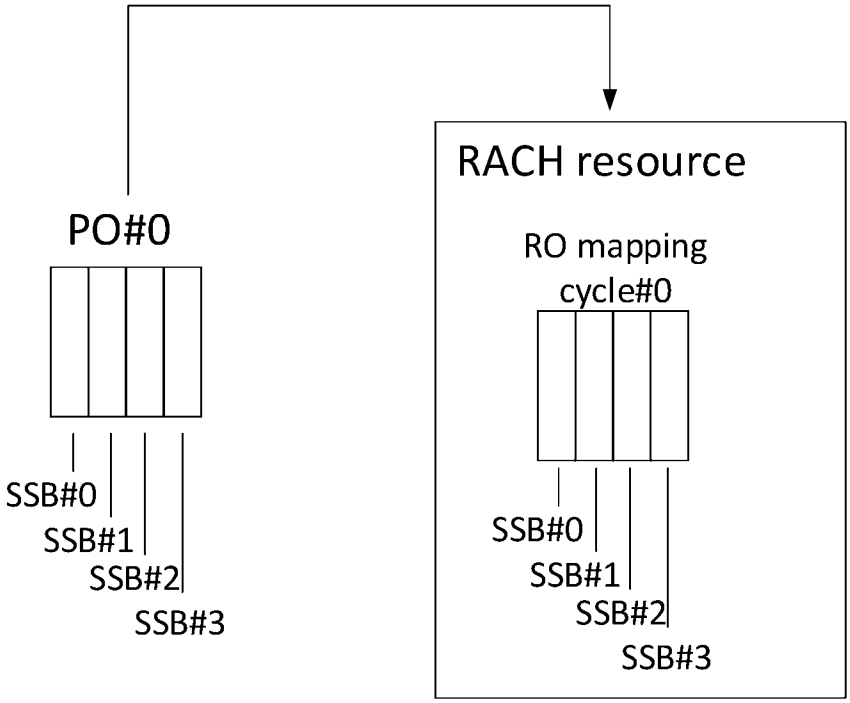
RACH resource
PO#0
RO mapping
cycle#0
SSB#0
SSB#1
SSB#2
SSB#3
SSB#0
SSB#1
SSB#2
SSB#3

FIG. 3

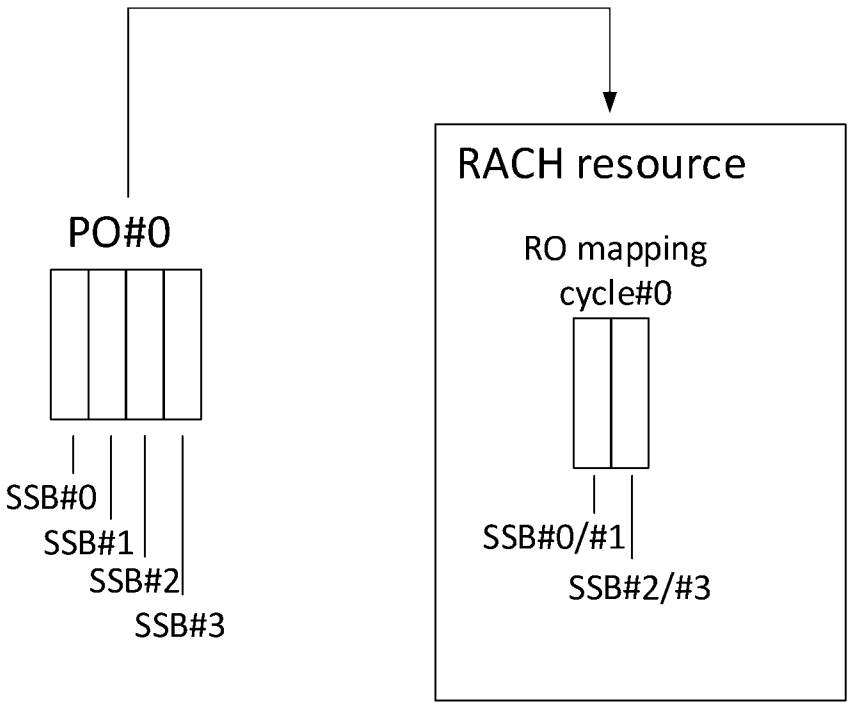
RACH resource
PO#0
RO mapping
cycle#0
SSB#0
SSB#1
SSB#2
SSB#3
SSB#0/#1
SSB#2/#3

FIG. 4

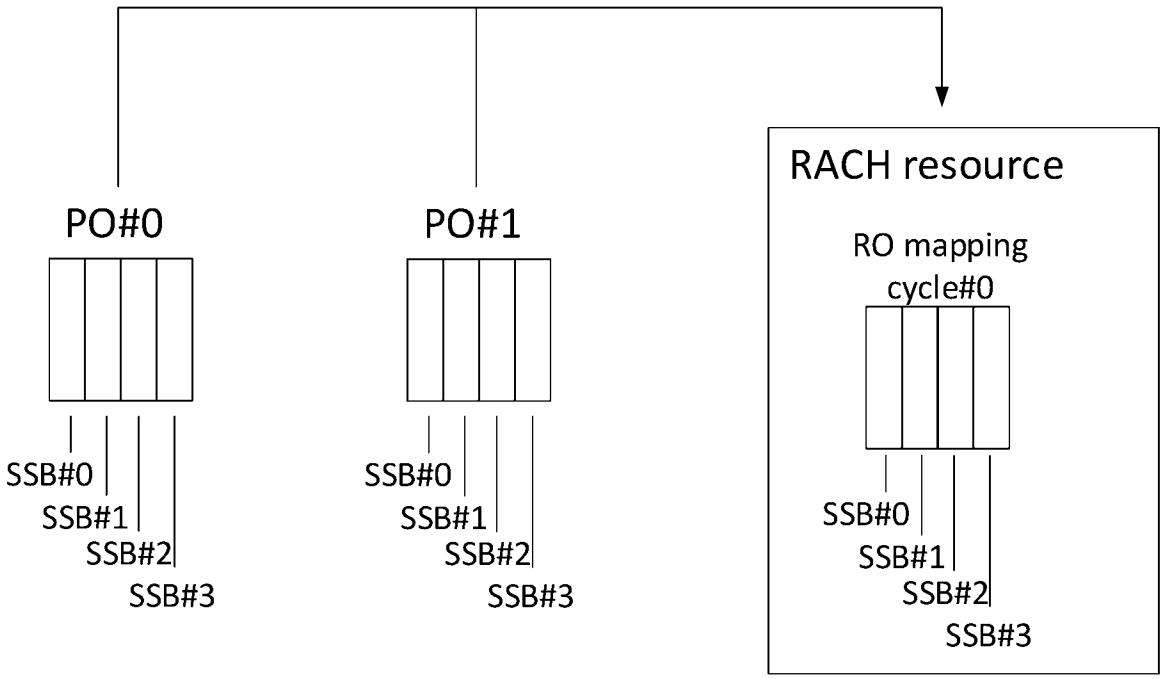
PO#0
PO#1
SSB#0
SSB#1
SSB#2
SSB#3
SSB#0
SSB#1
SSB#2
SSB#3
RACH resource
RO mapping cycle#0
SSB#0
SSB#1
SSB#2
SSB#3

FIG. 5

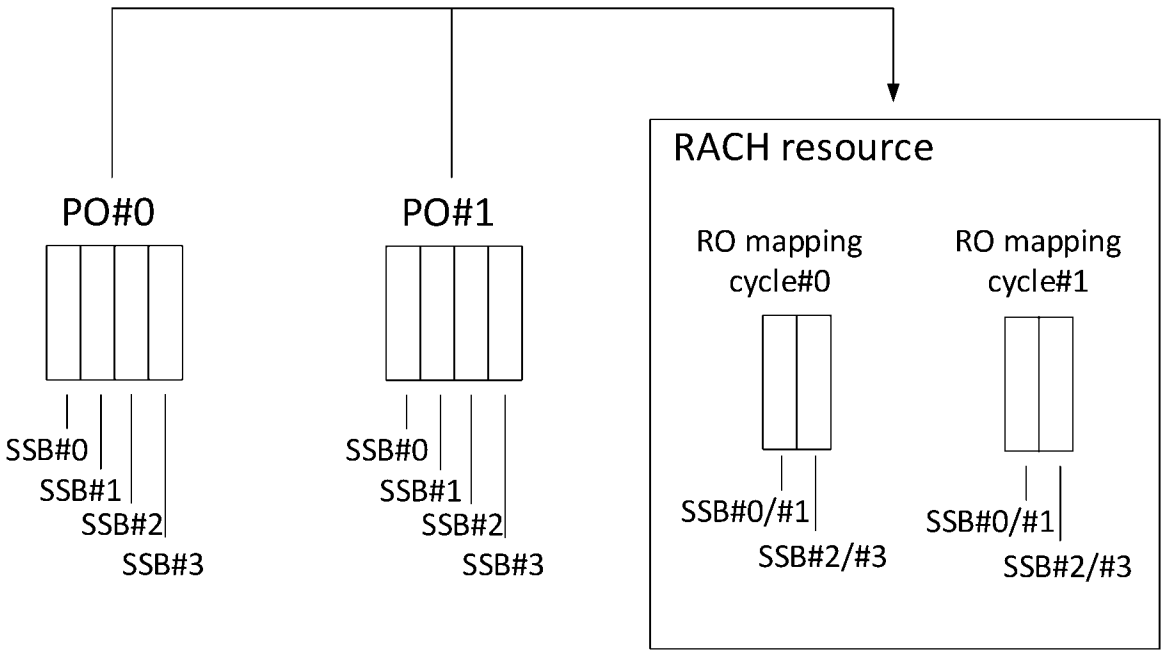
PO#0
PO#1
SSB#0
SSB#1
SSB#2
SSB#3
SSB#0
SSB#1
SSB#2
SSB#3
RACH resource
RO mapping cycle#0
RO mapping cycle#1
SSB#0/#1
SSB#2/#3
SSB#0/#1
SSB#2/#3

FIG. 6

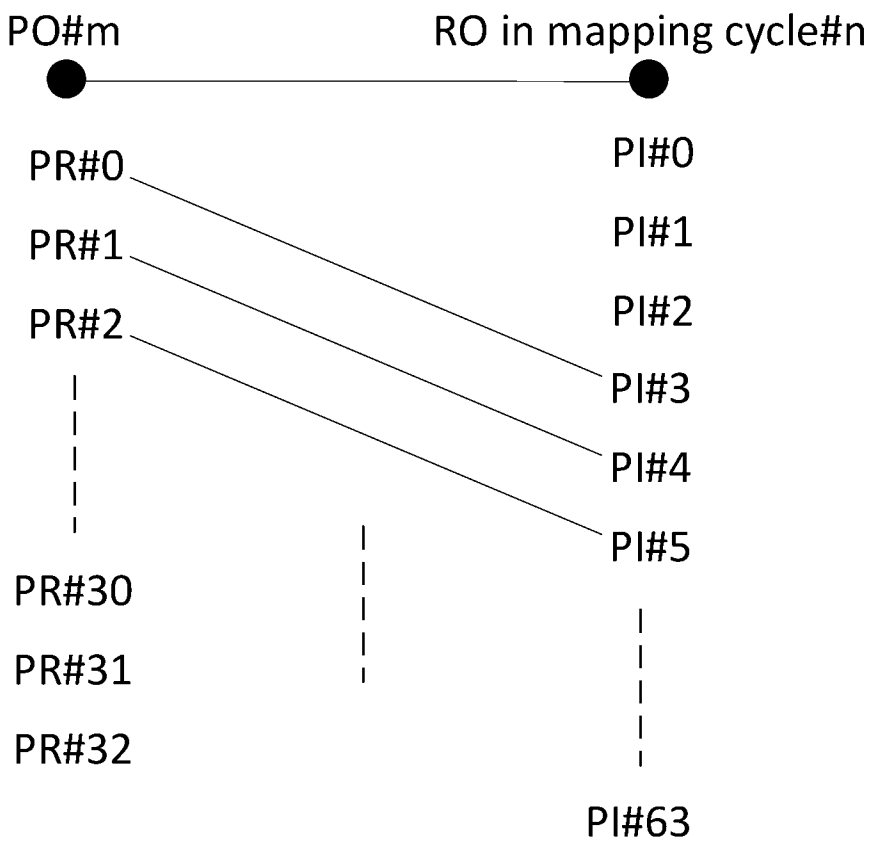
PO#m
RO in mapping cycle#n
PR#0
PR#1
PR#2
PR#30
PR#31
PR#32
PI#0
PI#1
PI#2
PI#3
PI#4
PI#5
PI#63

FIG. 7

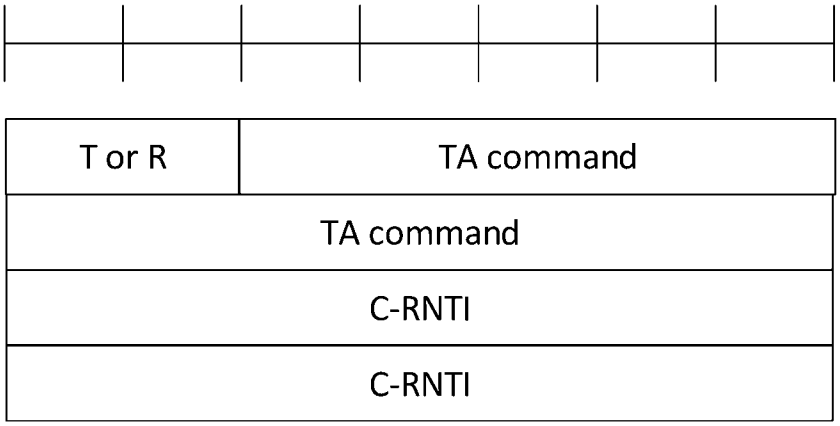
T or R
TA command
TA command
C-RNTI
C-RNTI

FIG. 8

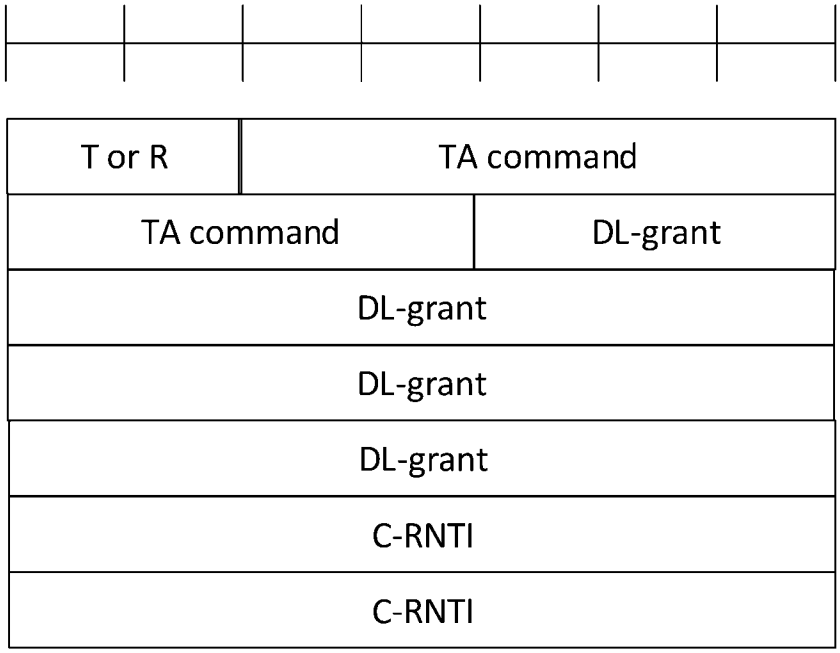
T or R
TA command
TA command
DL-grant
DL-grant
DL-grant
DL-grant
C-RNTI
C-RNTI

FIG. 9

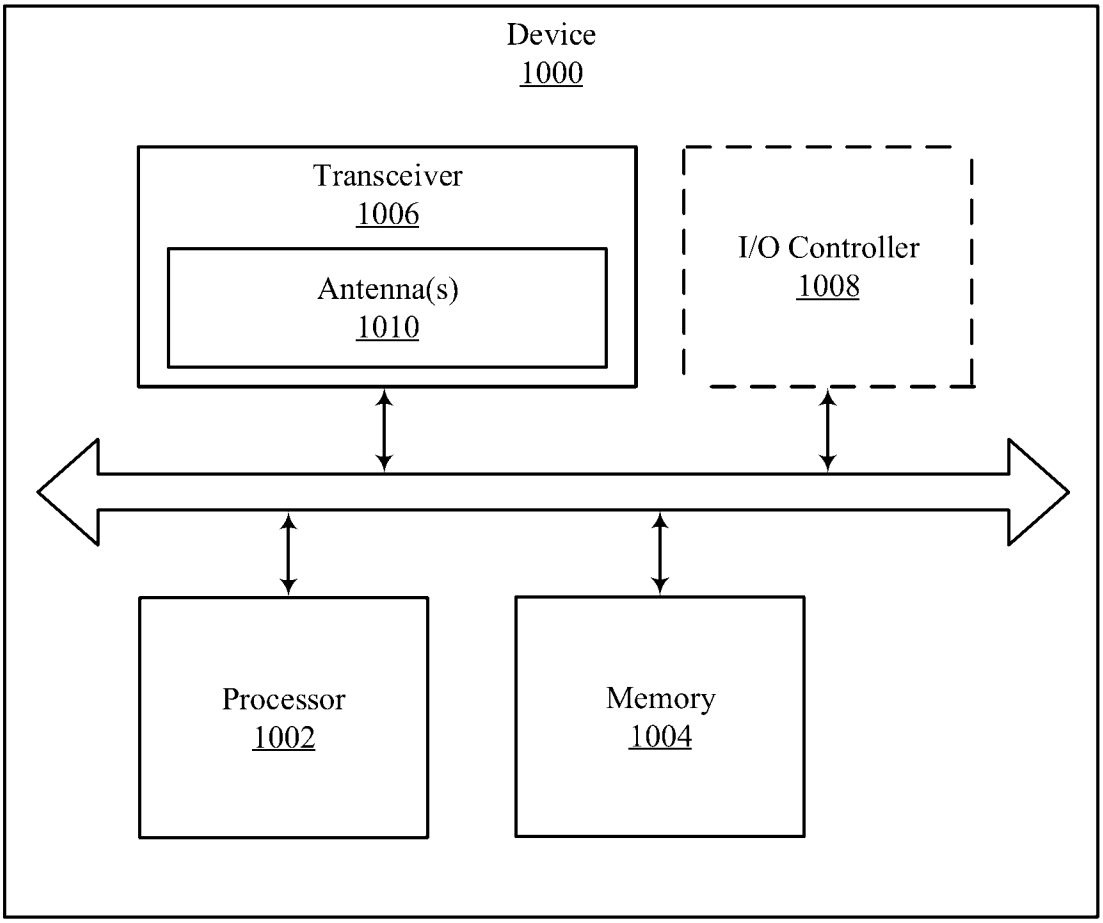
Device
1000
Transceiver
1006
Antenna(s)
1010
I/O Controller
1008
Processor
1002
Memory
1004

FIG. 10

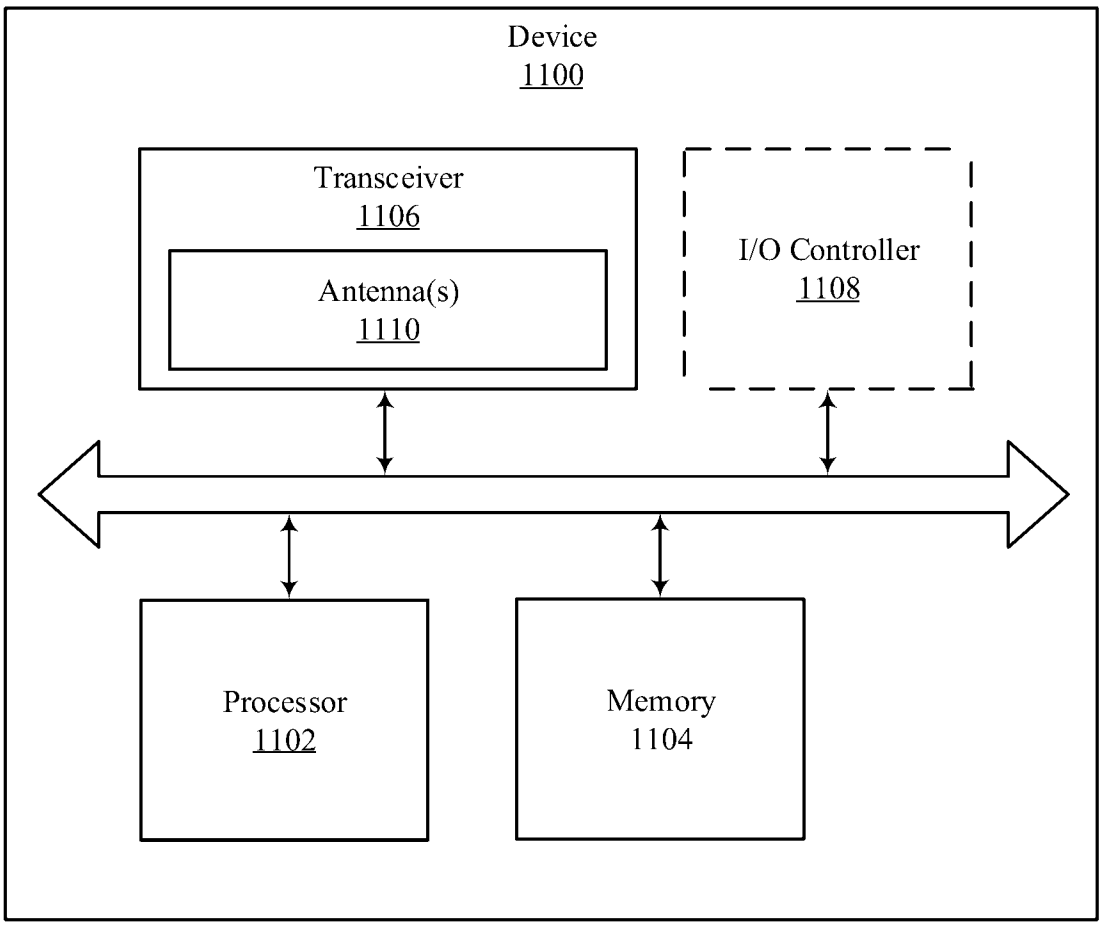
Device
1100
Transceiver
1106
Antenna(s)
1110
I/O Controller
1108
Processor
1102
Memory
1104

FIG. 11

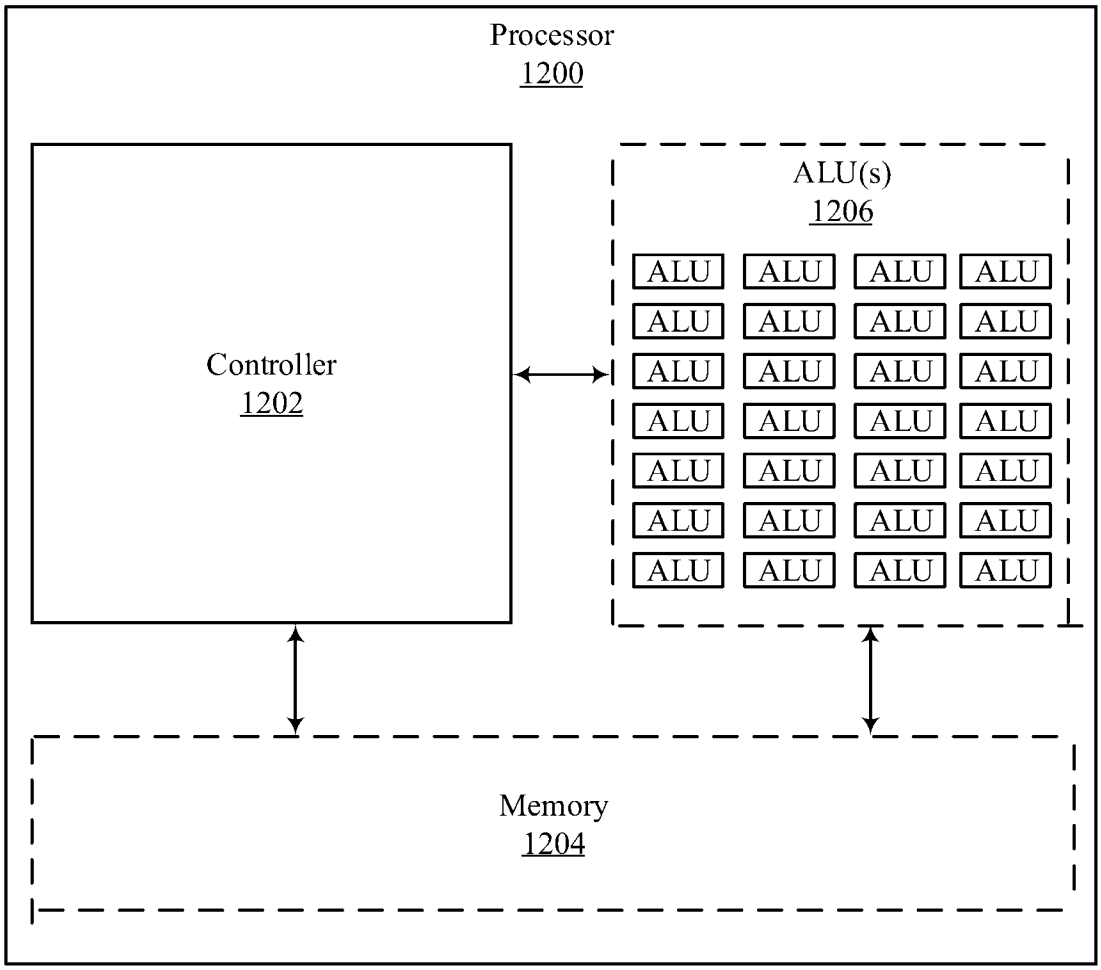

FIG. 12

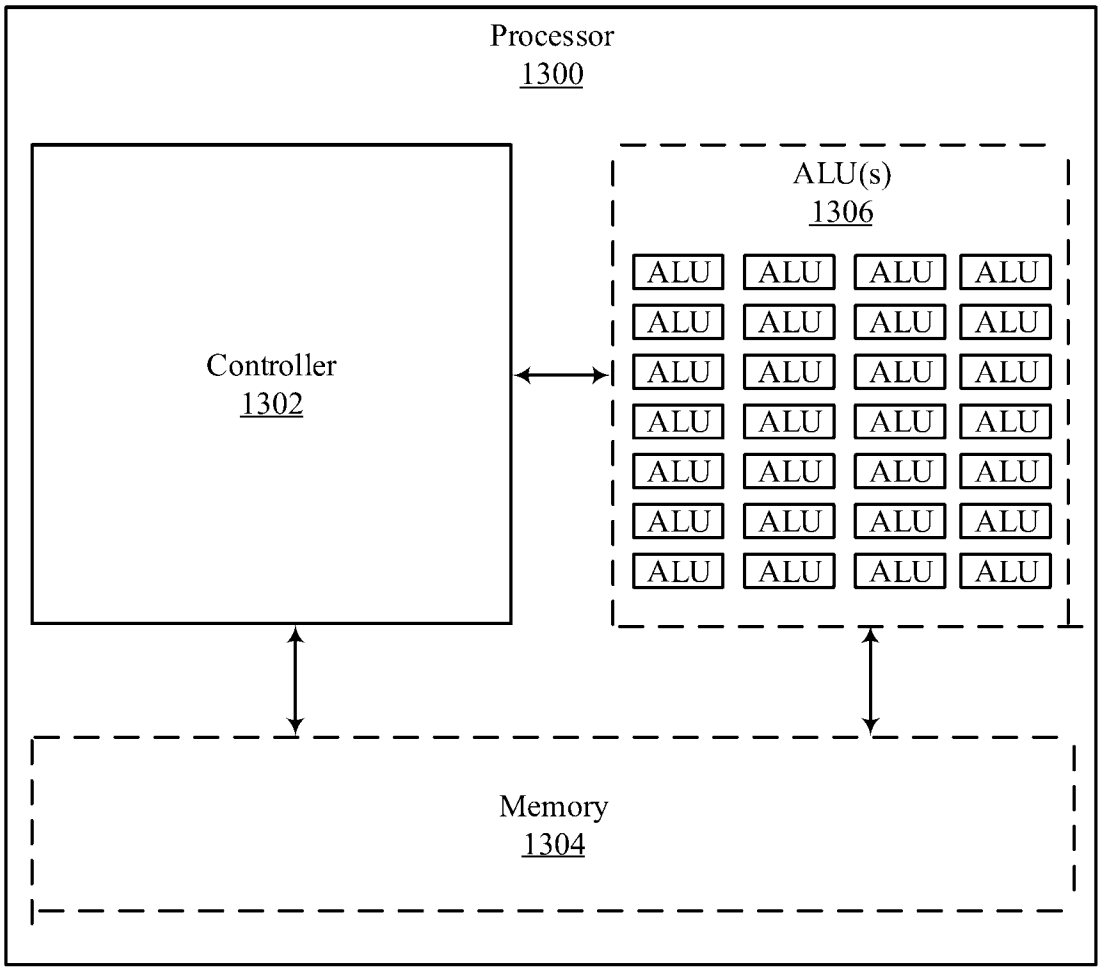

FIG. 13

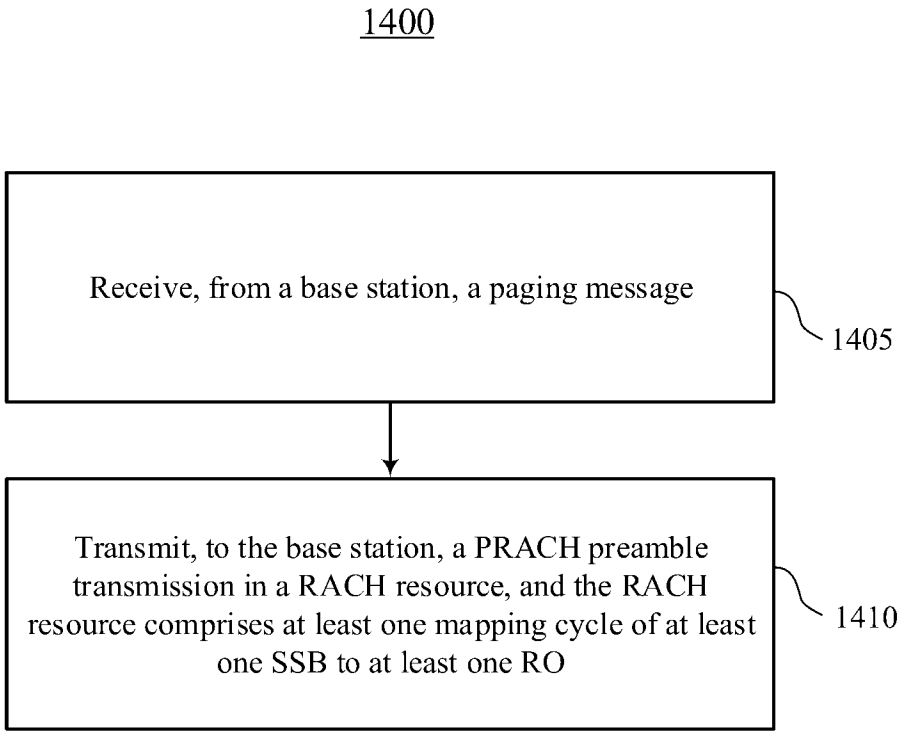
1400
Receive, from a base station, a paging message
1405
Transmit, to the base station, a PRACH preamble transmission in a RACH resource, and the RACH resource comprises at least one mapping cycle of at least one SSB to at least one RO
1410

FIG. 14

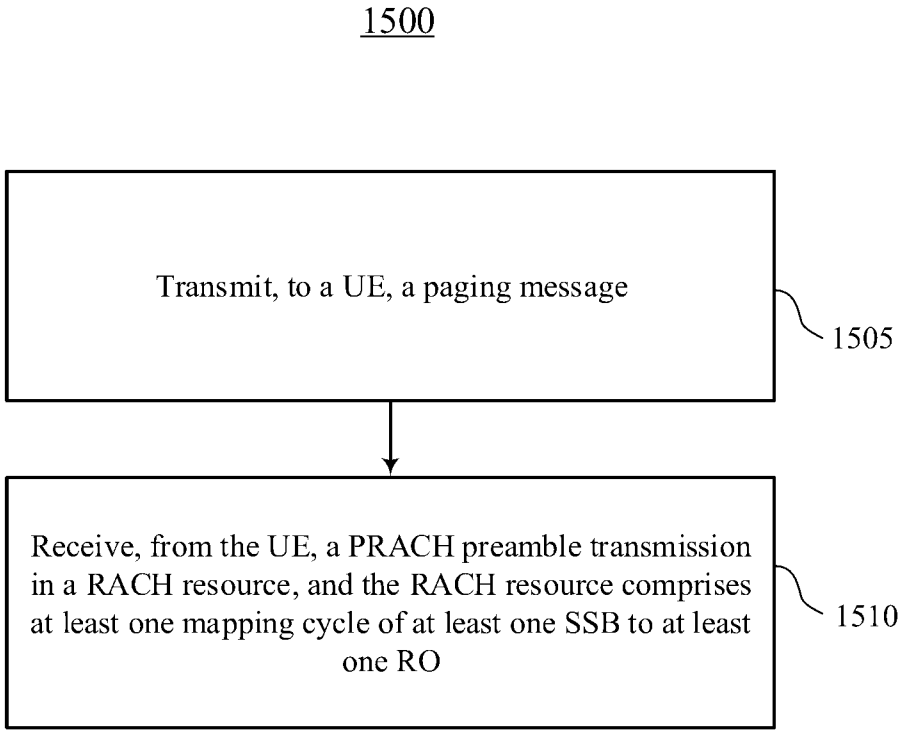
1500
Transmit, to a UE, a paging message
1505
Receive, from the UE, a PRACH preamble transmission in a RACH resource, and the RACH resource comprises at least one mapping cycle of at least one SSB to at least one RO
1510

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/109867

A. CLASSIFICATION OF SUBJECT MATTER

H04W74/0833(2024.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H04W,H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, ENTXT, DWPI, 3GPP: PRACH, RACH, resources, SSB, RO, occasion, map+, cycle, paging occasion, PO, associat+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2024073949 A1 (LENOVO(BEIJING) LIMITED) 11 April 2024 (2024-04-11) paragraphs [0067]-[0208], figures 2-9	1-16
A	US 2022369385 A1 (QUALCOMM INCORPORATED) 17 November 2022 (2022-11-17) the whole document	1-16
A	CN 114073163 A (TELEFONAKTIEBOLAGET LM ERICSSON(PUBL)) 18 February 2022 (2022-02-18) the whole document	1-16
A	SPREADTRUM COMMUNICATIONS. "Discussion on SBFD random access operation" *3GPP TSG RAN WG1 #117 R1-2404024*, 24 May 2024 (2024-05-24), the whole document	1-16

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2025	**17 April 2025**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/109867

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2024073949 A1	11 April 2024	None	
US 2022369385 A1	17 November 2022	None	
CN 114073163 A	18 February 2022	EP 3997954 A1	18 May 2022
		WO 2021004337 A1	14 January 2021
		US 2022256610 A1	11 August 2022
		CN 119485767 A	18 February 2025
		IN 202247006071 A	11 March 2022